Internet-Scale Data Acquisition and Control Systems

Programming Paradigm Challenges

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A Few Definitions

- Transducer
  - A sensor or actuator that converts between physical phenomena and electrical signals
- Transducer-Enabled System
  - Any object, simple or complex, which has one or more sensors or actuators transducing physical parameters of the object
- Data Aggregation
  - The process of reducing multiple sensor readings into a single unit
    - Either a bundled package containing the individual readings, or a fusion/filtering of the readings into fewer/one reading(s)

Introduction

- Premise: the Internet is entering a new phase
  - Machine-to-machine interactions at the core (M2M)
  - Data acquisition and automation on a grand scale
- Some key accelerators/enablers
  - Reduced communication component costs
  - MEMS impact on transducer innovation and cost
- Connected transducers integrate physical systems
  - Extend paradigm of hybrid physical/digital systems to Internet
  - Provide vast new sources of data: *information* $\Leftrightarrow$ *value*
- DER provide an ideal problem space for the evolving distributed nature of data acquisition and control systems
  - As requirements drive energy systems to become more distributed, information technology is developing in parallel to manage those resources more effectively

Introduction

- When transducers become networked, we can look for multiple, orthogonal uses of their data streams
  - Existing transducer-based systems getting connected
    - Automotive: heavy use of transducers; that data can now be distributed beyond the vehicle
- New functions such as location- aware computing driving integration of transducers
  - Mobile devices with integrated GPS
- In many cases, data that was of limited interest in isolation becomes valuable in aggregate
  - Active suspension and other data from vehicles, combined with GPS location and time stamps, enables creation of dynamic traffic flow and road condition models

Problem Statement

- As billions of transducers become connected via the Internet, can we create a new control systems programming paradigm that addresses the scale and distributed nature involved?
  - We need to promote a paradigm that focuses on higher level abstractions of physical systems, to enable increasingly complex control systems to be decomposed and managed

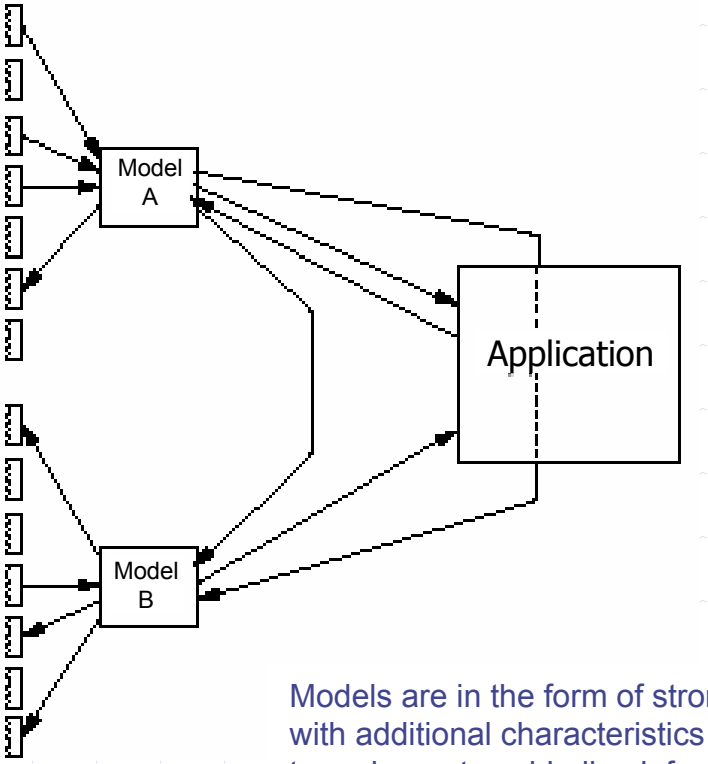
Unique Technical Challenges

- Develop an effective but simple programming paradigm for building systems based on Internet connected transducers
  - Capture physical abstractions in a standardized, programmatic fashion
- Integrate traditional data acquisition and control system techniques into a distributed programming environment
  - e.g., process modeling, negative/ positive feedback, fail safe, . . .
- Address new challenges introduced by the Internet
  - Communication latency and availability
  - Scale: the number of potential data collection and control points
  - Open communication infrastructure: privacy and security
- Incorporate privacy assurance and authentication into the base architecture at the start, not as an afterthought

Model-based Paradigm

An object may have a number of transducers available

Depending on the application requirements, a model can make use of one or more



In developing an application, the model's simplified view of the object is accessed

An application might consume values, update values, bind values to other models directly, or process values before feeding them to other models

Models are in the form of strongly typed attribute- value pairs with additional characteristics such as input vs. output, transducer- type binding information, data- quality requirements (e.g., update frequency, maximum latency, etc.)